MERCURY CONCENTRATIONS IN WATER AND SEDIMENT IN RESURRECTION CREEK, ALASKA

Preliminary Report
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ABSTRACT

- Water and sediment samples were collected at 5 sites on Resurrection Creek and its side channels on May 6, 2004, during moderate to high flow conditions. The samples were analyzed for mercury, methylmercury, and other parameters.

- This sampling is the first of 2 sample runs during 2004 to assess the presence or absence of mercury in the system prior to channel restoration work.

- This follows a fish sampling study conducted in the same reach in September 2003. Resident fish were found to have mercury levels elevated over reference levels but low compared to regulatory standards and levels from fish in disturbed and undisturbed streams nationwide.

- Total mercury concentrations in water ranged from 5.1 to 7.3 parts per trillion (ppt), with little difference between the reference reach and the project reach. Methylmercury comprised about 1 to 3% of the total mercury in the project reach side channels.

- These levels are far below the state and federal standards for drinking water, and similar to levels measured in other streams in the Cook Inlet basin.

- Total mercury in sediment in the side channels ranged from 42 to 141 parts per billion (ppb) dry weight, with the highest levels in the Beaver Pond side channel. Methylmercury comprised less than 2% of the total mercury in these samples.

- These levels are below the threshold effects level suggested as a preliminary screening level by NOAA, and are similar to levels measured in other streams in the Cook Inlet basin.

- Mercury levels measured in water and sediment in Resurrection Creek are low and pose little risk to drinking water contamination or aquatic species. Mercury levels may be elevated as a result of past mining operations, but sampling efforts have not detected any large concentrations of mercury.

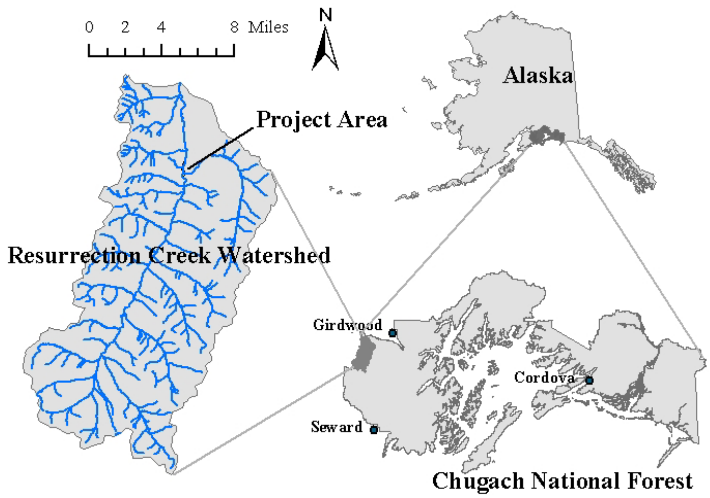
- Additional water and sediment sampling is planned for August 2004, during low flow conditions.

INTRODUCTION

The Chugach National Forest is planning a large-scale stream restoration project on Resurrection Creek, north of Hope, Alaska (**figure 1**). Resurrection Creek is the site of extensive gold placer mining over the past century, and placer mining operations in the early 1900's resulted in numerous tailings piles, channelization, and loss of floodplain functionality. Although it is unknown how much mercury was used for mercury amalgamation during these placer mining operations, some mercury may still be in the system, likely within the tailings piles.

This study was conducted to address concerns that some of this mercury might be released into the environment during channel restoration. The objectives of this study are to sample water and sediment to determine the presence or absence of mercury and methylmercury in the system, and compare the mercury concentrations between the reference reach, project reach main channel, and project reach side channels. Several other parameters are also measured to correlate with mercury levels. Sampling is to be conducted twice during 2004. This report presents the preliminary results from the first set of sampling, conducted on May 6, 2004 during high water conditions. The second set of sampling will occur in August 2004, during low water conditions.

Figure 1: Location of the Resurrection Creek project area.



CONTEXT

History: Resurrection Creek experienced a gold rush in the early 1900's. The town of Hope served as a mining camp for the numerous placer mining operations that operated on Resurrection Creek, Bear Creek, and the lower portion of Palmer Creek. Miners used heavy equipment to move parts of the channel and mine the channel material, resulting in large tailings piles deposited on the floodplains, some as high as 40 feet. The tailings piles have greatly confined the channel and its floodplain and remain largely unvegetated because of the coarse nature of the material and the lack of fine sediment. Overall, approximately 4 square miles of Resurrection Creek were highly disturbed, from about 2 miles to about 6.5 miles upstream of the mouth.

Mercury Amalgamation: Placer mining generally resulted in a slurry of heavier materials, or "black sands," that included tiny specs of gold that settle out during the sorting process. Elemental mercury has been used historically during placer operations to extract the tiny gold particles from the slurry. The mercury is mixed with the "black sands" and bonds directly to the gold particles, making a mercury amalgam. The mercury amalgam is more easily separated from the black sands than the individual gold flakes.

In the gold separation process, some of this mercury can be spilled directly into the stream or the mine tailings. Large scale gold placer operations in California during the 1850's to 1880's made extensive use of mercury for gold separation. Such operations reportedly lost an estimated 10 to 30% of the mercury they used and left thousands of pounds of mercury at each placer mine site (Saiki, 2003). It is unknown how much mercury was used or may have spilled into the environment during placer mining operations on Resurrection Creek in the early 1900's. Anecdotal evidence suggests that mercury was used, but not in the quantities of the earlier California placer operations.

Mercury: Mercury is naturally present in the environment from geologic sources as well as anthropogenic sources such as industrial metal manufacturing and fuel combustion, runoff from mercury mines, and mercury used for gold mining. Mercury in the atmosphere is distributed globally. In 1995, the annual emission of mercury from the US from industrial and combustion sources totaled 158 tons (US Environmental Protection Agency, 1997). Mercury generally remains in soils for long periods of time, slowly releasing mercury compounds to the environment. In Resurrection Creek, any elemental mercury spilled into the river likely settled into the substrate because of its high density and low solubility. In the project area, the alluvial deposits from Resurrection Creek comprise a thin layer, in places less than 3 feet thick, over a clay layer possibly deposited by a glacially dammed lake that existed during the Pleistocene. It is likely that any mercury that has settled into the sediment will ultimately stop at this clay layer.

Methylmercury: Bacteria within fine-grained and organic sediments can transform elemental mercury into methylmercury, a highly toxic form of mercury. This process generally occurs under anaerobic conditions. Methylmercury is readily absorbed or ingested by organisms, and it is transported to all organs, particularly affecting the nervous system. In fish, mercury toxicity generally has the largest effect on neurodevelopment of fertilized eggs and young developing fish. Mercury is highly insoluble in water except when attached to dissolved organic material. Because methylmercury bioaccumulates in organisms, levels of mercury in fish tissue can be orders of magnitude higher than mercury concentrations found in resident water and sediments.

Recent History: Large-scale hydraulic mining on Resurrection Creek ceased in the 1940's. Heavy equipment mining continued on some sections of the creek through the 1980's. Mining activity has decreased since the 1980's but still occurs in some areas, primarily as small-scale suction dredging operations. Between 1999 and 2002, fisheries personnel from the Chugach National Forest constructed a series of side channels and small ponds adjacent to Resurrection Creek, about 5 miles upstream of its mouth. These channels and ponds were constructed amongst the large tailings piles on both sides of the creek and are fed by French drains. They were built to improve rearing habitat for juvenile salmon in Resurrection Creek. These channels and associated ponds currently support moderate populations of salmon fry, as well as sculpin and other fish species, and represent some of the only slow-water pool habitat within the proposed restoration project reach.

Restoration: The Chugach National Forest is planning a large-scale restoration project for 0.8 miles of the Resurrection Creek channel and floodplain upstream and downstream of the Palmer Creek confluence. This area is referred to as the "project reach," and a reference reach exists about a mile upstream (**see figure 3**). The purpose of this restoration project is to restore the channel to its natural, self-maintaining form, restore functionality to the floodplain, and provide and improve stream habitat for fish and riparian habitat for mammals and birds. This will require redistributing and removing the tailings piles, creating a new channel, and restoring the channel and floodplain.

Documentation: In conjunction with a study on mercury concentrations in fish in Resurrection Creek conducted in September 2003 (MacFarlane, 2004), this study assesses the potential concentrations of mercury in the system prior to conducting restoration. Chugach National Forest personnel are currently developing an Environmental Impact Statement for the restoration project. Detailed studies of all aspects of the area were also recently conducted as part of the Resurrection Creek Watershed Association Hydrologic Condition Assessment (Kalli and Blanchet, 2001) and the Resurrection Creek Landscape Analysis (Hart Crowser, Inc., 2002).

HYDROLOGIC CONDITIONS

Watersheds: The Resurrection Creek watershed covers about 103,230 acres (161 square miles) on the northern side of the Kenai Peninsula. Resurrection Creek flows north about 24 miles into Turnagain Arm, and elevations in the watershed range from sea level to about 5,000 feet. The valley and side valleys are glacially carved U-shaped valleys, but glaciers are no longer present in the watershed. Numerous high gradient tributaries flow into Resurrection Creek, and the largest tributary, Palmer Creek, flows from a hanging valley east of the project area.

Climate: The Resurrection Creek watershed has a cool and moist climate. The average mean temperature at Hope, Alaska is about 37 degrees F (Western Regional Climate Center, 2003). Annual precipitation for Hope at the mouth of the watershed is about 22 inches, and annual precipitation increases to about 40 inches at the head of the watershed. The Resurrection Creek watershed lies in a rain shadow created by the Kenai Mountains and receives considerably less precipitation than watersheds to the east. Hope receives about 90 inches of snow annually, and snowfall increases with elevation. August, September, and October are the wettest months, and winters receive more precipitation than summers.

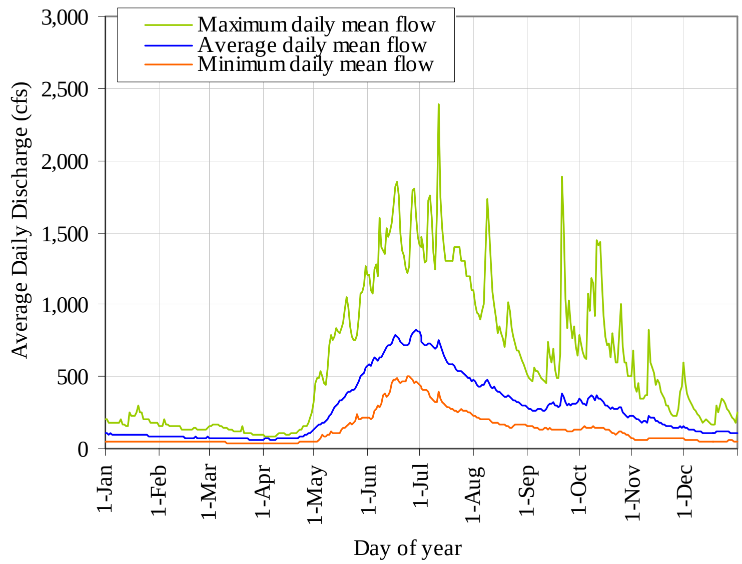
Streams: Based on the Region 10 stream classification system (USDA Forest Service, Alaska Region, 1992), Resurrection Creek progresses from a Moderate Gradient Mixed Control channel in its upper reaches to a Floodplain channel in its lower reaches, with several short canyon sections along its length. The channel within the project area is a Low Gradient Floodplain Channel, with a gradient less than 2% and a cobble and gravel substrate. Portions of the channel that were not placer mined have well-developed floodplains, but channels in the project area, as well as mined areas downstream, are confined on one or two sides of the channel by high, steep gravel and cobble tailings piles. These tailings piles do not allow for channel migration and decrease floodplain functionality. Palmer Creek joins Resurrection Creek near the upstream end of the project reach. This channel has a high gradient as it descends from a hanging valley, resulting in an alluvial fan at the confluence.

Side Channels: Near the upstream end of the project reach and upstream of the Palmer Creek confluence, two French drains on the east side of Resurrection Creek feed 2 small side channels (**see figure 3**). "Channel 1" is about 750 feet long and connects several small ponds. The French drain feeding Channel 1 does not function properly, and flows are generally very low. "Channel 2" contains 3 small ponds and is only about 400 feet long, fed by a functioning French drain. Beavers persistently build small dams on these channels. On the west side of Resurrection Creek, the "Beaver Pond Channel" starts near the Palmer Creek confluence and re-enters Resurrection Creek about 2700 feet downstream, at the end of the project reach. This channel has a series of small and large beaver ponds. A portion of the channel splits to join Resurrection Creek about 800 feet downstream of the French drain.

Streamflows: A stream gauge was in operation on Resurrection Creek upstream of Hope from 1967 to 1986. The average mean daily flow was 274 cfs (US Geological Survey, 2004). The flow regime in Resurrection Creek is primarily controlled by summer snowmelt (**figure 2**). Peak flows, averaging about 800 cfs, generally occur in late June to early July. Heavy fall rainstorms result in high magnitude, short duration peak flow events and a secondary peak in the hydrograph in October. These fall peaks are generally not as large as the summer snowmelt runoff peak. Winter flows from December to April average around 80 to 100 cfs. Ice buildup in the channel is common, and ice dam breakout floods can occur in the winter. The 2-year flow is about 1230 cfs, and the 10-year flow is about 2390 cfs (Curran et al., 2003).

Water quality: Water quality data were collected on Resurrection Creek near Hope from 1950 to 1959 and from 1968 to 1971 (US Geological Survey, 2004). These data indicate no violations of the state standards for fish and wildlife (Alaska Department of Environmental Conservation, 2003). Data collected in 1980 at placer mining sites on Resurrection and Palmer Creeks showed elevated levels of manganese and lead in the mining wash water, elevated levels of lead in Resurrection Creek downstream of the mining, and elevated levels of lead in Palmer Creek upstream of the mining (Blanchet, 1981). Lead concentrations were as high as 0.17 ppm, and manganese concentrations reached 0.22 ppm. We are not aware of any existing data for mercury in water or sediments of Resurrection Creek.

Figure 2: Resurrection Creek hydrograph, USGS station 15267900. Period of record 1967-1986.



PREVIOUS STUDIES

A study of mercury concentrations in resident fish in the Resurrection Creek project reach was conducted in September 2003 (MacFarlane, 2004). Results of the fish study showed that total mercury concentrations in sculpin and coho tissue ranged from 0.0297 ppm to 0.143 parts per million (ppm) wet weight in the main channel and side channels of the project reach, and 0.0315 ppm to 0.0318 ppm wet weight in the reference reach side channels. These levels are well below the 1.0 ppm "action level," at which the Food and Drug Administration restricts consumption of fish.

The highest concentrations of mercury in sculpin were found in the small artificial side channels of the project reach, where more stagnant water, higher temperatures, decreased oxygen, and increased organic matter may have led to increased methylation of mercury. Although mercury levels in sculpin were somewhat elevated in the project reach side channels, these levels are low compared to mercury levels in fish in degraded as well as non-degraded systems throughout North America. Data suggest that mercury levels measured in fish in Resurrection Creek and its side channels were not high enough to be toxic to resident fish or developing eggs and fry.

SAMPLING LOCATIONS AND METHODS

Sample mediums: Mercury concentrations can be analyzed in soil, sediment, water, fish tissue, or other organic samples. If miners did spill mercury, it could be concentrated in specific areas, but no such areas have yet been located. For this study, water and sediment were sampled in Resurrection Creek to determine what mercury concentrations may be present, and to further address any concerns about mercury in the system prior to restoration. Because mercury bioaccumulates in aquatic species, mercury concentrations in sediment and water are likely to be orders of magnitude lower than those in fish.

Sample locations: On May 6, 2004, water samples were taken at a total of 5 sites, including 3 side channel sites, 1 main channel site in the project reach, and 1 main channel site in the reference reach (**figure 3**). Methylmercury samples were taken only in the 3 side channel sites. As a result of the coarse substrate in the main channel, sediment samples were also taken only in the 3 side channel sites.

SC-CH1: Water and sediment samples were taken from Channel 1, at the downstream end of "Pool 1," the 5th pond downstream of the French drain. Samples were taken where the flow comes together in a 3-foot wide channel. The flow was very low because the French drain was not functioning properly. Leaves and other organic material were abundant on the bottom of the pond, and the water quickly became murky when the substrate was disturbed. Below the layer of organic material, the substrate was mostly sand and gravel. The banks were mostly vegetated. Samples were taken 2 feet from the left bank, where the water depth was 1 foot.

SC-CH2: Water and sediment samples were taken from Channel 2, in the "Berm Pool," immediately downstream of the Channel 2 French drain. Samples were taken at the downstream end of the pool, where the channel narrows to 6 feet wide. Leaves and organic material were abundant on the bottom of the pond, and the water quickly became murky when disturbed. Below the layer of organic material, the substrate was mostly sand and gravel. The sand and gravel banks at this site were bare and unstable. Samples were taken 3 feet from the left bank, where the water depth was 1.5 feet.

SC-BP: Water and sediment samples were taken from the Beaver Pond channel, at the upstream end of the third large beaver pond from the end of the channel. Samples were taken where flow begins to slow down and spread out into the pond. This large pond contains dead tree trunks and down logs, with very fine sediments, organics, and vegetation growing within the channel. Samples were taken just downstream of a small log cluster, about 12 feet from the left bank, where the water depth was 1.7 feet.

RC-DS: Water samples were taken from the main channel of Resurrection Creek at the downstream end of the project reach, about 60 feet downstream of the outlet of the Beaver Pond side channel. The main channel at this site is relatively steep, with high water velocities, and the substrate is gravel and cobbles. The left bank is a high, eroding bank composed of gravel and cobbles. Samples were taken about 10 feet from the left bank, where the water depth was about 2 feet.

RC-REF: Water samples were taken from the main channel of the Resurrection Creek reference reach, about 1 mile upstream of the project reach, and about 200 feet upstream of the inlet to the western side channel, in a riffle just upstream of a small slough on left bank. Samples were taken about 25 feet from the left bank, where the water depth was about 1.3 feet.

Sampling methods: All sampling bottles and equipment were pre-cleaned at the laboratory prior to shipping. Bottles were kept in double zip-lock bags. Because these samples were analyzed for ultra-trace levels of mercury, "ultra-clean" techniques were used when handling bottles and conducting sampling to prevent contamination of the samples (US Environmental Protection Agency, 1996). Sample bottles were handled only wearing non-powdered latex gloves by the sampler designated "clean hands." The field assistant, designated "dirty hands," handled only the outside of the outer zip-lock bag, never touching the sampling bottles. Latex gloves were changed at each sample site. Samples were frozen overnight and shipped overnight delivery to the laboratory in a cooler packed with ice. Samples were kept below 4 degrees C.

Water samples: For mercury and methylmercury samples, water was collected in 500 mL fluoropoly bottles with hydrochloric acid preservative. Water samples for sulfate and dissolved organic carbon were collected in 500 mL and 250 mL plastic bottles with no preservative. Samples were taken about 6 inches below the water surface, capped immediately, and placed on ice in a cooler. Water samples were not filtered. Water temperature and dissolved oxygen were measured at the time of sampling using a YSI Model 55 DO meter.

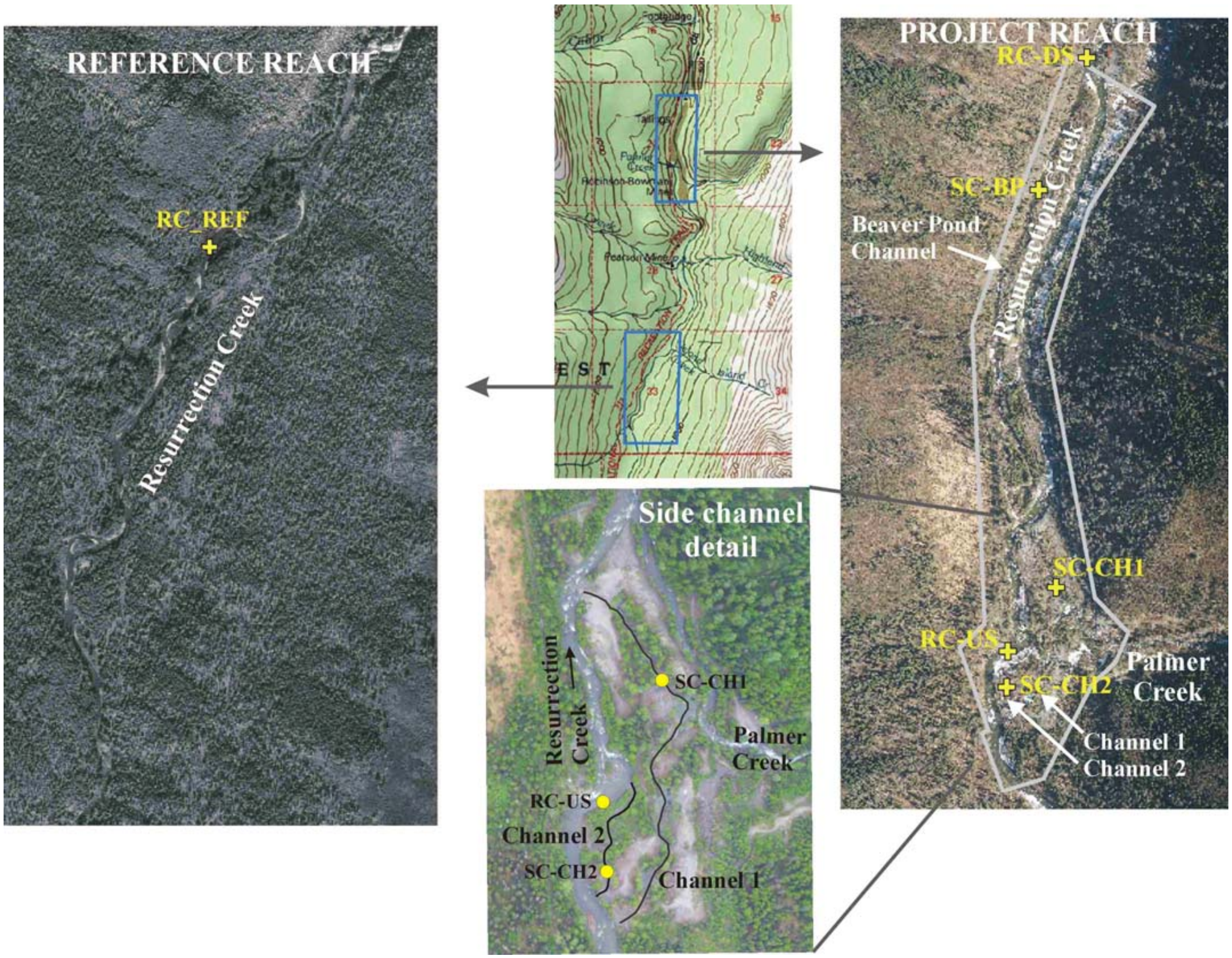
Sediment samples: Sediment samples were collected in 8-ounce wide-mouth glass jars for mercury and 4-ounce wide-mouth glass jars for methylmercury. Sediment was scooped from the substrate using a laboratory-cleaned 16-ounce wide-mouth jar. Samples were capped immediately and placed on ice in a cooler.

Laboratory methods: Laboratory analyses were conducted by Columbia Analytical Services, Inc., in Kelso, Washington. Methylmercury analyses were subcontracted by Brooks Rand LLC, in Seattle, WA. Samples were analyzed for mercury using EPA Method 1631E (US Environmental Protection Agency, 2002). This involves oxidation of the sample, followed by purging of the mercury onto a gold trap. Mercury is then detected using a cold-vapor atomic fluorescence spectrometer (CVAFS). Quality control included analysis of sample blanks and measurement of the percent recovery of a matrix spike in sample duplicates.

Samples were analyzed for methylmercury by a modification of EPA draft method 1630, as detailed in the Brooks Rand Method BR-0011. Sample preparation involved distillation of water samples and acid bromide/methylene chloride extraction of sediment samples. Samples were analyzed by cold vapor atomic fluorescence detection (CVAFS). Quality control included analysis of sample blanks and measurement of the percent recovery of a matrix spike in sample duplicates.

Water samples were analyzed for sulfate using ion chromatography as detailed in EPA method 300.0 (US Environmental Protection agency, 1999). Water samples were analyzed for dissolved organic carbon using EPA method 415.1. Sediment samples were analyzed for total organic carbon using method ASTM D4129-82M.

Figure 3: Locations of sampling sites on Resurrection Creek and side channels.



RESULTS OF SAMPLING

Sampling was conducted on May 6, 2004. The flow in Resurrection Creek was moderate to high, and the water was relatively turbid. This was the result of several days of dry, unseasonably warm temperatures prior to sampling, resulting in a rapidly depleting snowpack. Snow was almost completely melted from the lower valley bottom. The flow in the reference reach was about 1 foot below bankfull, and the gauge height at the Hope Highway ranged from 2.15 to 2.20 feet during the day.

Water samples: Total mercury concentrations in water samples ranged from 5.1 to 7.3 parts per trillion (ppt), with the highest level recorded in the Channel 1 pond site (**table 1, figure 4**). Methylmercury concentrations ranged from 0.089 to 0.193 ppt in the side channel sites, with the highest concentration in the Channel 1 pond site. Methylmercury comprised 1.6 to 2.6% of the total mercury. Sulfate ranged from 4.9 to 5.1 mg/L, and dissolved organic carbon ranged from 4.2 to 5.3 mg/L. Water temperatures ranged from 3.7 degrees C in the reference reach to 6.6 degrees C in the Channel 1 pond.

Table 1: Results of mercury sampling in water and sediment in Resurrection Creek.

			Resurrection Creek				
			SC-CH1	SC-CH2	SC - BP	RC - DS	RC-REF
		Detection Limit	Channel 1, Pool 1	Channel 2, Berm pool	Beaver Pond channel	Downstream end of project reach, main channel	Reference Reach, main channel
Water	Total Mercury (ppt)	0.1	7.3	5.6	5.1	6.0	5.7
	Methylmercury (ppt)	0.045	0.193	0.089	0.119	-	-
	Percent of total as Methylmercury (%)	-	2.6	1.6	2.3	-	-
	Sulfate (mg/L)	0.18	5.1	5.1	5	4.9	5.1
	Dissolved organic carbon (mg/L)	0.07	4.5	4.9	5.3	4.2	5.1
	Water temperature (degrees C)	-	6.6	5.7	6.2	6.5	3.7
	Dissolved oxygen (mg/L)	-	8.3	11.1	11.2	11.3	12.3
Sediment	Total percent solids (for total Hg analysis)	-	80.6	66.8	20.5	-	-
	Total Mercury (ppb)-dry weight	0.3	55.1	42	141	-	-
	Total organic carbon (%) -dry weight	0.02	0.46	0.46	10.2	-	-
	Total percent solids (for Me-Hg analysis)	-	78.2	75.9	33.5	-	-
	Methylmercury (ppb) - dry weight	0.02	0.651	0.066	1.797	-	-
	Percent of total as Methylmercury (%)	-	1.2	0.2	1.3	-	-

Sediment samples: Total mercury concentrations in sediment samples ranged from 42 to 141 parts per billion (ppb) dry weight basis in the side channel sites, with the highest level recorded in the Beaver Pond side channel (**table 1, figure 5**). Methylmercury concentrations ranged from 0.066 to 1.797 ppb dry weight basis in the side channel sites, with the highest concentration in the Beaver Pond channel. Methylmercury comprised 0.2 to 1.3% of the total mercury. Total organic carbon ranged from 0.46 to 10.2% dry weight basis.

Figure 4: Results of mercury sampling in water in Resurrection Creek.

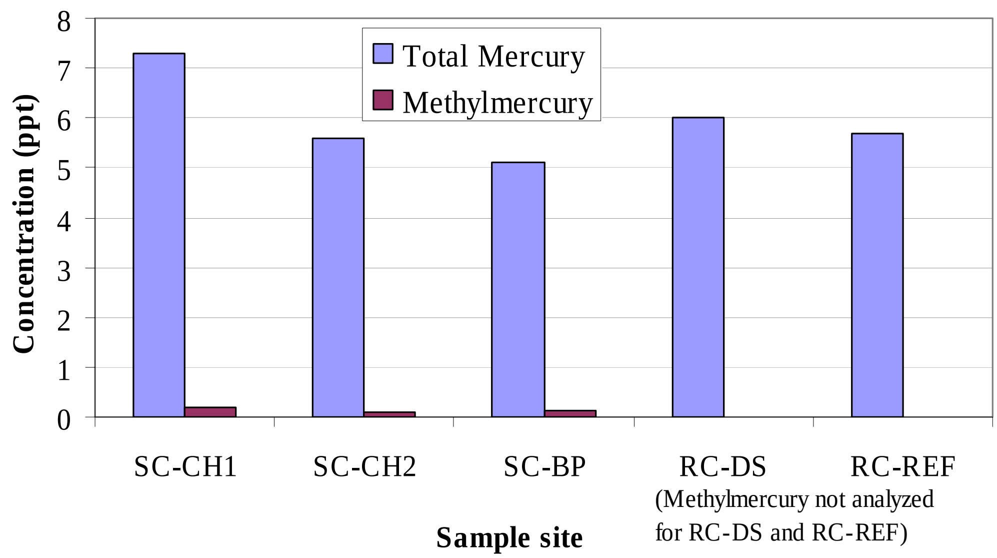
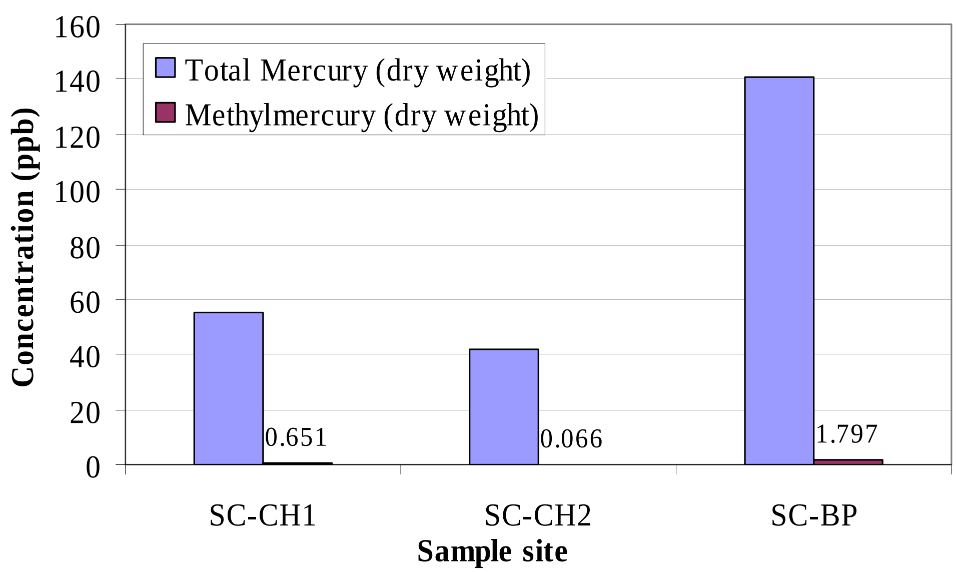


Figure 5: Results of mercury sampling in sediment in Resurrection Creek.



DISCUSSION

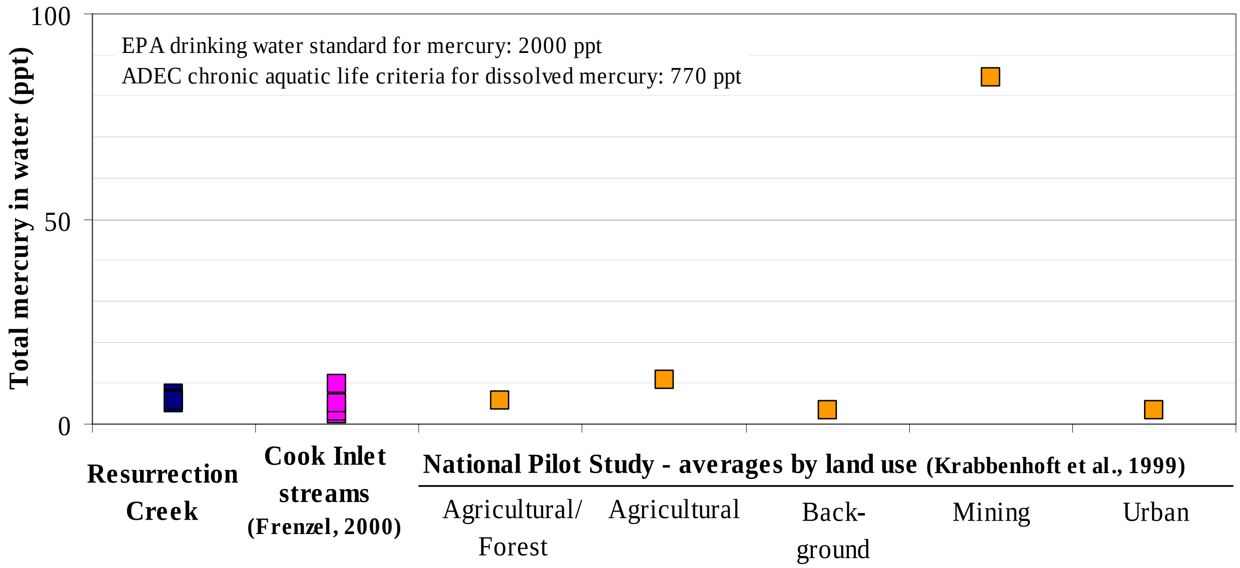
Mercury levels in water

Total mercury concentrations in water were relatively similar between the reference reach main channel, the project reach main channel, and the project reach side channels. The highest levels were in the Channel 1 site, the side channel with the lowest flow. Mercury levels in the project reach were not elevated over those of the reference reach. Streamflows were moderate to high on the day of sampling, and water moved relatively quickly through the project reach. However, the side channels exhibited slow-moving and sometimes stagnant water, which is retained within the project reach and among the tailings piles for extended periods. The fact that mercury levels in the side channels were relatively similar to those of the main channel suggests that mercury is not abundant in this area.

The Alaska Department of Environmental Conservation (ADEC) primary contaminant limit for mercury and the US Environmental Protection Agency standard for mercury in drinking water are both 2 ppb, or 2000 ppt (Alaska Department of Environmental Conservation, 2003; US Environmental Protection Agency, 2004). The ADEC 1-hour acute aquatic life criteria for total dissolved mercury in fresh waters is 1.4 ppb (1400 ppt), and the 4-day average chronic standard is 0.77 ppb (770 ppt). Mercury concentrations in water samples taken from Resurrection Creek and its side channels were much lower than these water quality standards.

Numerous studies have been conducted on mercury in impaired and unimpaired streams nationwide and regionally. Wiener et al. (2002) suggested that total mercury concentrations in lakes and streams with no anthropogenic or geologic sources of mercury generally range from about 0.3 to 8 ppt. Total mercury concentrations in water in Resurrection Creek and its side channels were within this range and were similar to levels from samples taken on other Cook Inlet basin streams (Frenzel, 2000) (**figure 6**). Methylmercury levels in Resurrection Creek were generally higher than those in the Cook Inlet sites, although they were still a small percentage of the total mercury. Streams in which mercury mining, industrial pollution, or gold mining occur can exceed 10 ppt, to over 1000 ppt (Wiener et al., 2002). As an extreme example, the Dutch Flat mining district in California, an area that was extensively placer mined using mercury amalgamation processes in the 19^{th} Century, contains streams with as much as 10,400 ppt mercury in unfiltered water samples and 225 ppt mercury in filtered samples (Hunerlach et al., 1999). A national pilot study of mercury concentrations in a variety of locations and land uses suggests that streams under most land uses have mercury and methylmercury concentrations similar to those in Resurrection Creek, but the average total mercury concentrations in areas associated with mining greatly exceeds those of Resurrection Creek (Krabbenhoft et al., 1999) (**figure 6**).

Figure 6: Comparison of ranges of total mercury concentrations in water between Resurrection Creek and other sites nationwide.



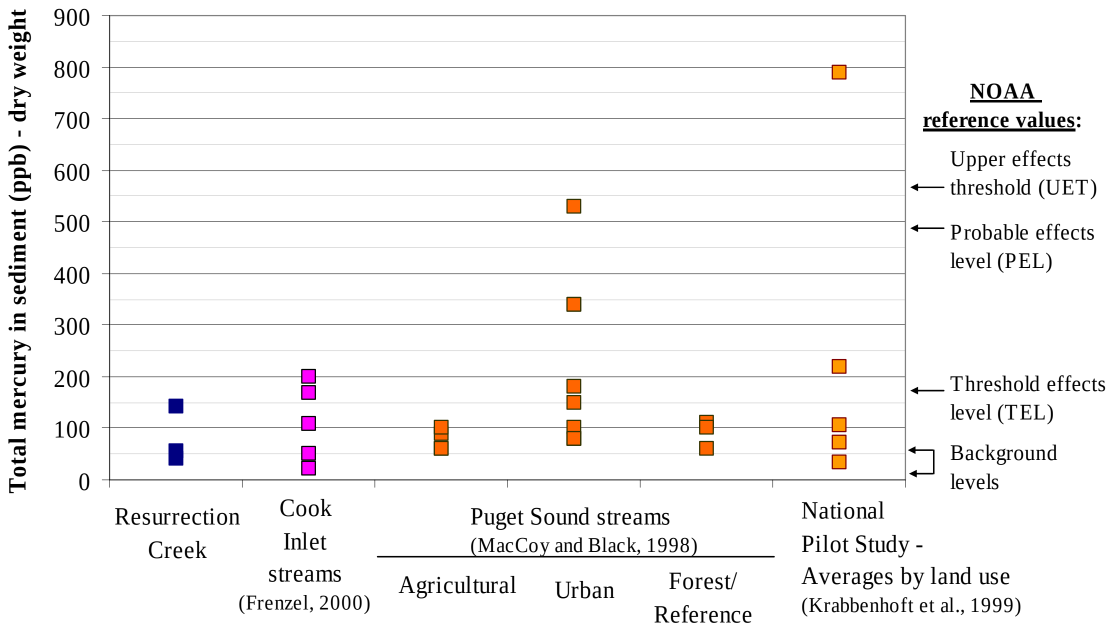
Mercury levels in sediment

Total mercury levels in sediment were about 3 times higher in the Beaver Pond channel than the other project reach side channels. The Beaver Pond site contained considerably finer substrate than the other sites, including more organic matter, whereas the other 2 samples contained mostly sand and gravel.

Preliminary screening levels for mercury contamination in sediment have been suggested by the National Oceanic and Atmospheric Administration (NOAA). Although they do not represent sediment quality standards, these guidelines suggest that background levels of mercury are about 4 to 51 ppb (dry weight). For total mercury in freshwater sediment, the Threshold Effects Level is 174 ppb (dry weight), the Probable Effects Level is 486 ppb (dry weight), and the Upper Effects Threshold is 560 ppb (dry weight) (National Oceanic and Atmospheric Administration, 1999). Mercury levels in the side channel sites were at the high end or over background levels, but below the Threshold Effects Level.

Total mercury and methylmercury levels in the Resurrection Creek side channels are similar to levels in the Cook Inlet sites (Frenzel, 2000) (**figure 7**). These levels are also similar to mercury levels in streams in agricultural and forested sites in the Puget Sound area, Washington, but considerably lower than the urban sites in the Puget Sound area (MacCoy and Black, 1998) (**figure 7**). Mercury and methylmercury levels in the Resurrection Creek side channels are within the lower range of levels measured in sediments from the national pilot study (Krabbenhoft, 1999) (**figure 7**).

Figure 7: Comparison of ranges of total mercury levels in sediment (dry weight) between Resurrection Creek and other sites nationwide.



Trends and analysis

Many factors have been shown to affect mercury and methylmercury concentrations in streams. Clearly, point sources of mercury pollution and geologic sources affect mercury concentrations in water and sediment. Atmospheric deposition of mercury from global sources can be a large contributor of mercury to surface waters. A study in the coastal basins of New England showed that precipitation contained total mercury concentrations of 2 to 20 ppt in 2002 (US Geological Survey, 2003). Although mercury is deposited globally in this manner, such influences are more prevalent in the more industrial areas. Research has shown that elevated water temperatures, low pH, anaerobic conditions, and higher dissolved organic carbon concentrations increase rates of methylation of mercury (US Environmental Protection Agency, 1997; Power et al., 2002). Krabbenhoft et al. (1999) showed that the density of nearby wetlands was the most important factor increasing methylation rates.

Mercury levels in Resurrection Creek show several of these trends, but the relationships are not strong because of the small dataset. In general, mercury and methylmercury increase with temperature, decrease with dissolved oxygen, and decrease with dissolved organic carbon. In sediment, mercury and methylmercury increase with total organic carbon. Because mercury is highly insoluble and generally exists in water attached to organic matter, higher levels of dissolved organic carbon are associated with higher mercury levels. Methylmercury is generally a small component of the total mercury concentrations in surface waters and sediments. Both total mercury and methylmercury are likely to be higher in the project reach side channels than in the main channel because of the more stagnant conditions, with bacteria that can cause methylation of mercury, and organic material to which mercury can bind in the water and sediment.

CONCLUSIONS

Preliminary data from the first of two sampling runs show that mercury levels are low in Resurrection Creek and its side channels. Mercury levels in the water in the project reach are not elevated above those of the reference reach and are similar to levels found in streams in the Cook Inlet basin. Mercury levels in sediment in the side channels are also within the range of levels found in streams of the Cook Inlet Basin. Mercury concentrations were highest in the fine-grained, organic sediments. It is likely that mercury and methylmercury are higher in the side channels of the project reach because of more abundant organic material, warmer temperatures, lower dissolved oxygen, and increased methylation of mercury.

These data support the low concentrations of mercury measured in resident fish in the same reach in September 2003. It is likely that mercury levels are somewhat elevated in the project reach as a result of deposition of mercury during past gold mining operations, but sampling efforts have not detected levels that would be of concern for drinking water or effects on aquatic species. Total mercury concentrations in Resurrection Creek were lower than those measured at other sites impacted by gold mining and mercury amalgamation processes nationwide. The second sampling run, scheduled for August 2004, will provide water quality data during lower flow levels.

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APPENDIX A: SAMPLE SITE PHOTOGRAPHS

SC-CH1: Project Reach side channel, east side (Channel 1, Pool 1)


SC-CH2: Project Reach side channel, east side (Channel 2, Berm Pool)


SC-BP: Project Reach side channel, west side (Beaver Pond Channel)


RC-DS: Project Reach main channel, downstream end of project reach, left bank

RC-REF: Reference Reach main channel, left bank

APPENDIX B: LABORATORY DATA

Laboratory analyses were conducted by

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